6. Contributions to our Knowledge of the Plankton of the Faeroe Channel.—No. VI.[1] Description of a new Mid-water Tow-net. Discussion of the Mid-water Fauna (Mesoplankton). Notes on *Doliolum tritonis* and *D. nationalis*, and on *Parathemisto abyssorum*. By G. Herbert Fowler, B.A., Ph.D., Assistant Professor of Zoology, University College, London.

[Received June 18, 1898.]

In the first paper of this series, I proposed to leave the description of the mid-water nets used, and the discussion of the general question of the existence of a mid-water fauna or Mesoplankton, until the collections made on the 'Research' had been thoroughly investigated. The net which I used last year proved so successful in actual working, that it now seems to me better to describe it at once for the information of other investigators, who might give it a further trial; the more so since my leisure for research work is but small, and the collections cannot be completely finished for some months to come.

It is unnecessary to describe here the numerous and varied forms of apparatus which have been devised for the capture of animals at known mid-water depths without admixture of the fauna from other zones. References to them will be found, by those interested, in the papers of Hoyle[2], H.H. the Prince of Monaco[3], and Agassiz[4]; since the appearance of the last-named, a full description of the 'National' apparatus has been published by Hensen[5]. Agassiz, in the paper cited, has subjected the earlier forms of net to a searching criticism, with which I agree on the whole; except that of the Prince of Monaco and that of the 'National,' none appear to exclude satisfactorily animals from undesirable zones. Even that of the Prince of Monaco does not appear to have worked satisfactorily on the 'Pola'; and the modification of Chun's net used on the 'National' was uncertain in its action[5].

When desirous to study for myself the question of a mid-water fauna or Mesoplankton[6], I feared that both the nets last quoted were too expensive, and the 'National' net too complicated for use in such heavy seas as are generally to be found in the Faeroe Channel, the only deep-water readily accessible to me. Returning therefore to Chun's[7] original ingenious design as a starting

[1] For Part I., see P. Z. S. 1896. p. 991; Part II., P. Z. S. 1897, p. 523; Part III., P. Z. S. 1897, p. 803; Part IV., *antea*, p. 540; Part V., *antea*, p. 550.

[2] Proc. Liverpool Biol. Soc. iii. 100.

[3] CR. Congrès international de Zoologie, Paris, 1889, p. 133.

[4] Bull. Mus. Comp. Zool. Harvard, xxiii. 1.

[5] Ergebnisse d. Plankton Exped.: Methodik der Untersuchungen p. 103 *et seqq.* (1895).

[6] For the explanation of this and similar new terms used here, see p. 545 *ante*.

[7] C. Chun: Bibliotheca Zoologica, i. 1

point, I endeavoured to introduce into it such improvements as would obviate what appeared to me to be its weaknesses, namely: (1) The position of the wires when the net had shut, which necessitate the mouth being always slightly open; (2) the lack of power to keep the net-mouth shut in a roll of the ship or a check on the line, as the attachments of the wires by which it then hangs are so close together; (3) the speed at which the whole structure must be towed in order that the screw-propeller, and the rod to which it is fixed, may overcome the frictional resistance offered by the rings on which the weight of the net is hanging.

I decided to construct a net for vertical and not for horizontal use, because it seems to me, on the basis of my small experience, impossible to be certain of the depth at which a net is being towed horizontally. The usual method for this is to lower the net vertically, and to begin towing with the rope straight up and down; then to observe the angle made by the rope with the horizon by means of a quadrant, and to calculate the vertical depth of the net by traverse tables on the assumption that the towing-line is the hypotenuse of a right-angled triangle. Unfortunately for this method, however, the towing-rope is not a hypotenuse, but forms an unknown catenary, which varies with the weight of the net, its resistance to the water, and the pace of towing; this forms an increasing source of error, the greater is the length of towing-warp out. As an example of the uncertainty of this method,—I struck bottom at 398 fathoms in the Faeroe Channel, when by quadrant and traverse tables the net should have been at 300 fathoms with 450 fathoms of rope out. There are so many forces at work as to make it impossible for any but a highly skilled mathematician to calculate the probable position of the net, and this only after tedious experiment.

Description of the Apparatus.

This consists of the net, the net-frame and chains, and the locking-gear. As the first of these were used both in 1896 and 1897, they will be described in detail; the locking-gear of the 1896 pattern will only be sufficiently sketched to enable future workers in this field to profit by my experience of failures; the 1897 pattern will be fully described.

The net is made of Swiss Silk Boulting Cloth, by far the best material known to zoologists for every form of tow-net; it was supplied by Messrs. Staniar of the Manchester Wire Works; this material will stand almost any fair pull, but, as it is very liable to be cut by anything sharp, when coming inboard, the actual net is surrounded by a loose case of common mosquito-netting. A net with a twenty-inch square mouth, tapered to a four-inch diameter cod-end, and six feet in length, was found to be a good working size. It should be sewn throughout by hand, not by machine; and with strong sewing-silk, not thread. If washed nightly in fresh water and dried in the air, a net of this sort will last for a very long time.

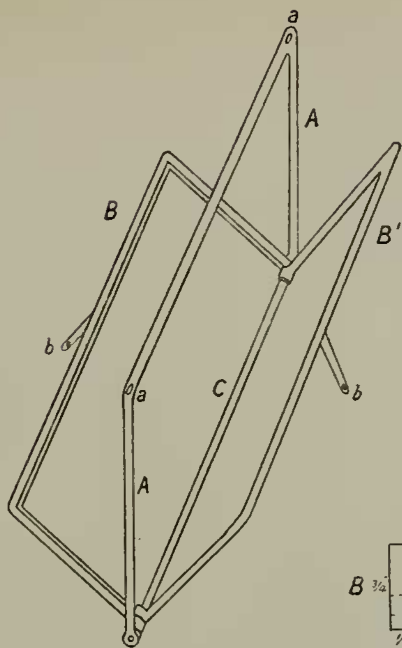

FIG. 1.

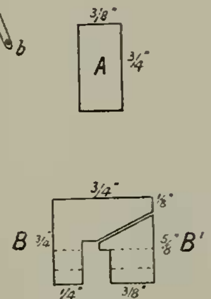

FIG. 2.

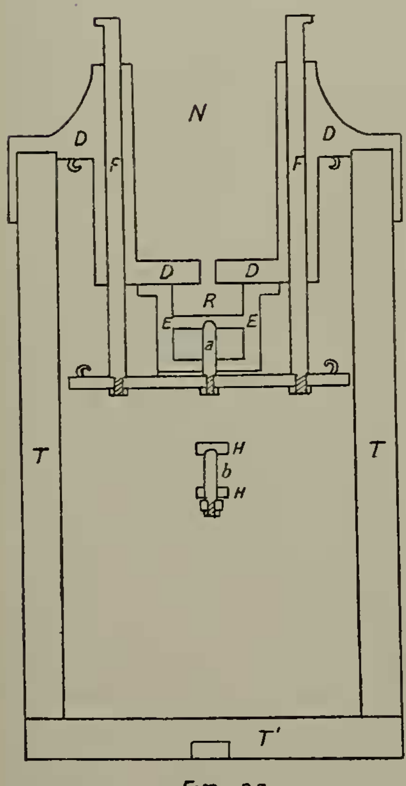

FIG. 3a.

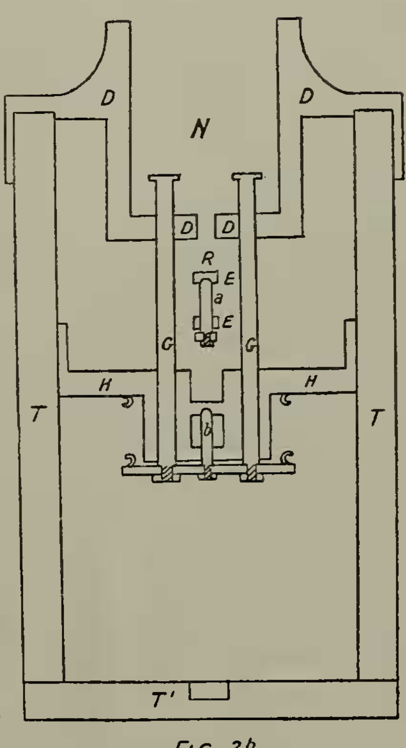

FIG. 3b.

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As a mid-water net has to be drawn up by a steam-winch more rapidly than is usual with a surface tow-net, even when the winch is going its slowest, boulting cloth of twenty-five (1896) and forty (1897) meshes to the inch was selected; of these the second is stronger and more efficient. If the winding-drum can be run dead slow by gearing, 50 or even 60 meshes to the inch might be used. A calico band at the mouth pierced by lacing-holes, and a calico band at the cod-end, with a tape by which the collecting zinc pot is tied in, complete the net. The tape should run in loops *outside* the calico band, it is there much easier to untie with cold wet fingers.

The **net-frame** (fig. 1, where it is represented as half open) consists of two ┌─┴─┐ shaped phosphor-bronze castings **BB′** hinged together on a solid brass axle **C**; on to the latter is also hinged, outside **BB′**, a wrought iron ┌───┐ shaped piece **A**, which is rather larger than the other two. The arms **bb** of **BB′** are drilled to take shackle-bolts from which chains pass upward to the locking-gear; two holes are also drilled at **aa** for similar shackle-bolts and chains. The net-frame in its descent is suspended from **bb**, and is therefore tightly closed by its own weight (about 15 lbs.) and by any additional weight that may be hung on the axle, the arms pressing **BB′** firmly together; when the chains from **bb** are slacked by the locking-gear, the net falls for a short distance, the weight is caught on to the chains from **aa**, and the net-mouth either falls open, or opens on the slightest pull in towing. The whole apparatus is then hauled upwards through the zone which it is desired to investigate (generally 100 fathoms). The chains from **aa** are then slacked by the locking-gear, the net falls a second time, and the weight, being caught on the chains from **bb**, again closes the net effectively.

In fig. 2 the sectional dimensions of **A**, **B**, **B′** are given, the net-frame being represented as closed. The upper end of the net itself, laced inside the frame, is compressed into the space between **B** and **B′**; the dotted lines indicate the lacing-holes drilled through the frame at intervals of an inch. When it is closed, only a Protozoan could get through the net-mouth, and even that would find a difficulty.—**B** and **B′** when open form a mouth twenty inches square (inside measurement); **A** is $\frac{3}{4}$ inch outside them when closed. The arms **bb** are seven inches long, and effect a good leverage for closing the net. They form one of the most important improvements on the original pattern. Even shaking the frame violently up and down when held by the chains does not open the net.

[The **locking-gear** of the 1896 pattern was arranged as follows:—Through the chains from **aa** and **bb** were passed the hammers of two reversed gun-lock movements, the hammer rising when fired; the lock of the **bb** chains was placed vertically below that of the **aa** chains. Parallel to the vertical between these two ran a long steel rod, tapped with a screw-thread: at the lower end of the steel rod was a screw-propeller, arranged so as not to revolve during the descent of the apparatus. When hauled upwards, however, the propeller began to revolve, travelled up the steel rod, and fired the trigger of the lower lock-movement, thus slackening the **bb** chains and allowing the net frame to fall open; still travelling upwards, as the apparatus was hauled in, the propeller presently fired the trigger of the upper lock-movement, slacked the **aa** chains, and the net then closed. The whole apparatus was prevented from spinning in its descent, and thus causing the propeller to begin travelling too soon, by being suspended from a swivel which worked on ball-bearings.

This arrangement worked successfully in about three hauls out of four, the failures being generally due to one or both chains hanging on the hammer, even when the lock-movement had been fired, owing to the great friction of the chains on the hammers. A further disadvantage in the apparatus was the difficult adjustment of the distance between the triggers, which determined the distance in fathoms for which the net remained open; this further had a tendency to vary somewhat with the rate of hauling in.]

In designing the **locking-gear** of the 1897 pattern I therefore abandoned the propeller in favour of messengers, which I had originally avoided on the grounds of others' experience with the light messengers of deep-sea thermometers. There seems, however, to be no objection to the use of *heavy* messengers on any well-stretched rope (hemp or wire) which hangs free of the bottom, and in which kinks are thus avoided by the maintenance of a steady strain.

Photographs of the whole apparatus are given on page 572. Details of the locking-gear are furnished by figs. 3 *a*, 3 *b* (p. 569), which are sectional drawings at right angles to one another. They are carefully drawn to scale, about one-seventh of the real size.

Four vertical pillars of teak[1] **T**, connected below by two cross-pieces of the same material **T′**, and strengthened by iron plates at the angles, form a rigid frame; on to this is screwed a brass casting **D**, to which a second casting **E** is screwed. The rope by which the machine is slung passes through a hole in the centre of **D** into the space **R** between **D** and **E**, and is kept there by being worked into a broad knot.

Two brass cylindrical rods or pins **FF** (fig. 3 *a*) run in two good bearings through **D** and are rigidly bolted into a cross-piece which carries a third shorter pin **a**, travelling in bearings through the centre of **E**. The pin **a** is passed through the chains from **aa** on the net-frame, and is kept in place by springs (not drawn) between the hooks shown in fig. 3 *a* with a pull of about 10 lbs. If a weight be dropped on to the pins **FF**, it will overcome the springs, depress the pin **a**, and let go the chains from **aa**.

A second pair of pins **GG** (fig. 3 *b*) run in bearings through **D**, and through another casting **H** which is bolted to **TT**. They are rigidly bolted to a cross-piece which carries a third pin **b**, travelling in bearings through the centre of **H**; this pin is passed through

[1] Teak is one of the few woods that will resist the enormous pressure at great depths; less closely grained woods warp and split.

Fig. 6.

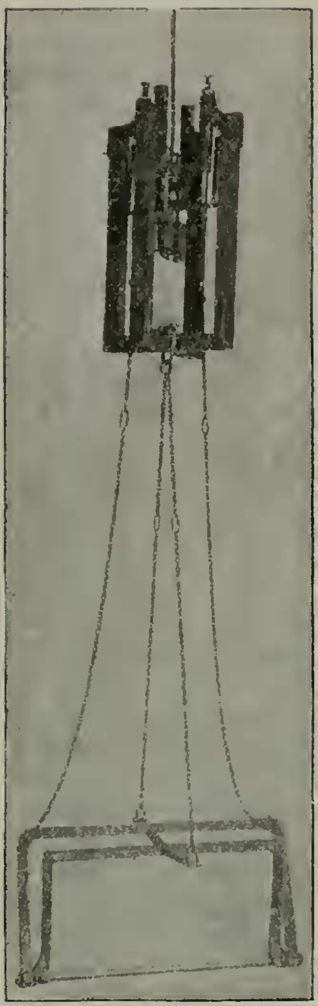

Fig. 5.

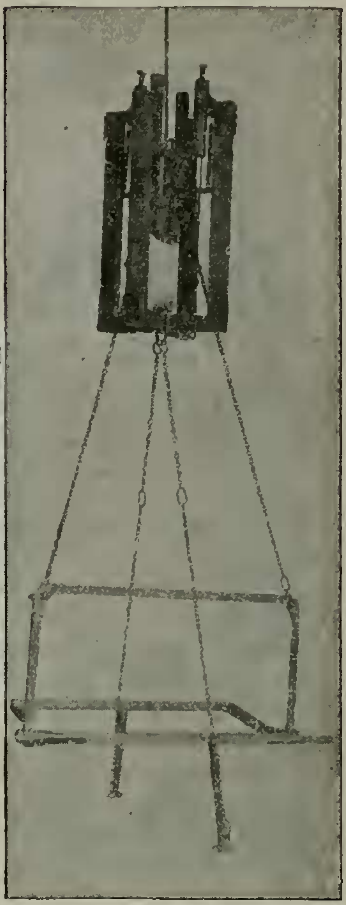

Fig. 4.

the chains from **bb** on the arms of the net-frame, and is kept in place by springs (rubber loops) between the hooks shown in fig. 3 *b*, with a pull of about 10 lbs. If a weight be dropped on to the pins **GG**, it will overcome the springs, depress the the pin **b**, and let go the chains from **bb**.

The apparatus is worked thus :—The whole machine is lowered with the locking-gear in the position drawn in figure 4, the chains **aa** held on the pin **a**, but not carrying the weight of the net and frame ; the chains **bb** held on the pin **b**, and holding the net-frame tightly closed by its own weight. When the machine is at the bottom of the zone which it is desired to study, the first messenger is despatched down the rope ; this, being small, drops into the nest **N**, striking on the pins **GG**, and freeing the chains **bb** ; the net-frame falls 6 inches, and opens, the weight being caught with a jerk on the chains **aa**.

The machine in this condition (fig. 5) is hauled upwards for a hundred fathoms ; the second and larger messenger is despatched, which, striking on the pins **FF**, frees the chains **aa** ; the net falls 15 inches, the weight is caught again on the chains **bb** ; the net-frame closes, and can be then hauled in-board without any admixture with the fauna of higher zones (fig. 6).

The chains of course are not let go altogether, as the net and frame would then be lost ; each chain has a large link in it to go over its pin, and beyond this a short length by which it is bolted to **T** or a shackle-bolt in the centre of **T**′.

	Chains **aa**.	Chains **bb**.
From net-frame to pin	33 in.	23 in.
From pin to **T**	9·5 in.	....
From pin to central bolt of **T**′..	....	12 in.

The messengers used in 1897 were clumsy and unnecessarily heavy, and will not be described here. Probably weights of 4 lbs. for the smaller and 6 lbs for the larger are amply sufficient on rope : smaller weights would do on wire, since the friction is less.

The apparatus was tested in 1897 on H.M.S. ‘Research,’ but, unfortunately, owing to heavy weather, we were only able to spend one day in the deep water of the Faroe Channel ; the apparatus was tried four times, and seemed to work perfectly. The only improvement which suggested itself was that a weight should be hung from the axle **C** into the middle of the net, heavy enough to prevent the net in its descent from washing up into the machinery (which happened once, but without serious consequences) ; the additional weight at this point will also serve to shut the net-mouth more closely, and can also be arranged to prevent the sides of the net compressing the contents when closed. Should the first messenger strike **FF** before **GG**, the net would simply come up empty, having been open only for a few seconds.

Weight of net-frame $16\frac{1}{2}$ lbs. ; of locking-gear and chains 33 lbs. ; of messengers used in 1897 ($7\frac{1}{2}+10$) $17\frac{1}{2}$ lbs. ; of messengers for future use (4+6) 10 lbs.; suggested above to be added at **T′ T′**, 10 lbs., and to be hung on **C**, 10 lbs.: total about 80 lbs.

At the conclusion of the four hauls, the net was sent down to 100 fathoms, and hauled up without the messengers having been despatched; it came up empty, although it had passed through the stratum where life was probably most plentiful. I am unable to see any source of error in the working of this apparatus, but hope that it may be given a further trial before long[1]. Of course, with an apparatus half a mile away from one in water, one cannot see what is actually occurring; one can only take precautions against every possible source of error, and may judge of their success to some extent by the character of the animals obtained.

Conclusions of Prof. Agassiz: the Azoic Zone.

In discussing the general results of the 'Albatross' Expedition in 1891[2], Prof. Agassiz reviewed the apparatus used and conclusions attained by earlier naturalists who had attempted a solution of the question of a Mesoplankton. His own views are based on experiments made during the cruises of the 'Blake' (1877–80) and the 'Albatross' (1891). On the first of these vessels he used the gravitating-trap[3] invented by Lieutenant-Commander (now Captain) Sigsbee, which not only failed to catch living organisms between 100 and 150 fathoms, but apparently missed even the corpses of the dead surface fauna! The machine is only stated to have been tried on two occasions, and only to a depth of 150 fathoms; from this Agassiz concluded[4] (p. 37) that "these experiments serve to prove that the pelagic fauna does not extend to considerable depths, and that there is at sea an immense intermediate belt in which no living animals are found, nothing but the dead bodies which are on their way to the bottom." On the 'Albatross' a new apparatus was tried, the invention of Captain Tanner, which is fully described and figured by Prof. Agassiz. On the basis of this he states[4] (p. 55):—"Our experience in the Gulf of California with the Tanner self-closing net would seem to indicate that in a comparatively closed sea, at a small distance from the land, there may be a mixture of the surface species with the free-swimming deep sea bottom species, a condition of things which certainly does not exist at sea, in deep water, in an oceanic basin at a great distance from shore, where the surface pelagic fauna only

[1] The cost of the apparatus should come to about £10, now that the patterns for casting have been made. If any zoologist will give it a further trial, I shall be glad to superintend its manufacture.

Since the above was written, my net has been taken for a further trial by the German Expedition which sailed on August 1st under Prof. Chun's direction, and Prof. Max Weber has ordered a net for the Dutch East-Indian Expedition.

[2] Bull. Mus. Comp. Zool. Harvard, xxiii. 1.

[3] Bull. Mus. Comp. Zool. Harvard, xiv. 36 (='Three Cruises of the Blake,' vol. i. p. 36, London, 1888, 8vo).

[4] Bull. Mus. Comp. Zool. Harvard, xxiii. 1.

descends to a comparatively small depth, *i. e.* about 200 fathoms, the limits of the depth at which light and heat produce any considerable variation in the physical conditions of the water. The marked diminution in the number of species below 200 fathoms agrees fairly with the results of the 'National' Expedition."

The other experiments with the Tanner net, made in an oceanic basin on the way to Acapulco from the Galapagos, and to the Galapagos from Cape San Francisco, "seem to prove conclusively that in the open sea, even when close to the land, the surface pelagic fauna does not descend far beyond a depth of 200 fathoms, and that there is no intermediate pelagic fauna living between that depth and the bottom, and that even the free-swimming bottom-species do not rise to any great distance, as we found no trace of anything within 60 fathoms from the bottom, where it had been fairly populated."

Prof. Agassiz therefore admits the existence of a deep Mesoplankton near land, but does not state how far from land and in what depth of water his generalization of an Azoic zone begins to hold good. I do not know of any later pronouncement by this eminent oceanographer on the question. Since then, Captain Tanner has improved his original pattern in detail [1], but the principle of his net remains the same. It is rash, and perhaps a little ungracious, to criticize the working of a net which one has never seen; but I venture to suggest, on the basis of the drawings and description of the Tanner nets, that a weak point in them is the way in which the tripping lines are suspended; it seems that it would be so very easy for them to slip off from the tumbler and close the net before they were intended to do so, under the alternate strain and slackening of the warp as the ship rolls; it also seems likely, and indeed Captain Tanner himself admits, that the angle made sometimes by the net-frame in turning would practically close the net's mouth. As regards the Sigsbee gravitating trap, there can, I think, be little doubt that it was too small and too violent to throw much light on the question of an Azoic zone.

Conclusions of the 'Challenger' and other Naturalists: the Mesoplankton.

Prof. Agassiz may be regarded as the chief representative of the school of naturalists which refuses to accept the alleged existence of a Mesoplankton. The chief supporters of the opposite view are the 'Challenger' naturalists (a distinguished band, of whom Sir John Murray is alone left), Prof. Chun, and Profs. Hensen and Brandt of the 'National' staff.

The 'Challenger' naturalists arrived at their belief from a comparison of serial tow-nets, stopped at intervals along the dredge-rope. As all the tow-nets were open throughout their course, the presence of particular species in the deep nets only seemed to indicate that these species occurred in the deep water only. The

[1] Z. L. Tanner, Bull. U.S. Fish Commission, xiv. p. 148.

method is theoretically excellent [1], but is not certain enough for use as an argument against the negative observations of the 'Blake' and 'Albatross.'

While I am fully in agreement with Professor Chun's results, it must be admitted that the original pattern of his net was not devoid of sources of error, which Agassiz was not slow to point out. Chun reported [2] an abundant fauna from all depths in the Mediterranean, but, this being a warm closed sea with a uniform temperature of 55° or 56° F. from 100 down to 2400 fathoms and more, no thermal barriers are here set to the vertical descent of an organism. It is not therefore possible to argue from this case to that of the great oceans, the temperature of which decreases with the depth until 30° F. or even less is reached.

Three hauls made by Prof. Chun on a voyage to the Canary Islands [3] revealed a Mesoplankton at great depths, the general character of which agreed with the similar captures of the 'Challenger' and 'National.' The net used was an improvement on the Mediterranean pattern: open nets were also employed in other hauls.

As regards the 'National' net, a modification of Chun's pattern, Prof. Agassiz expressed suspicion of the locking arrangement which closed it. Prof. Brandt was kind enough to show it to me some years ago in Kiel; it is extremely ingenious in mechanism, but, as Prof. Hensen [4] admits, it is most uncertain in its action; and, if I may judge from my own experience of a screw-propeller, it would not give very exact information of the depth; for the rate at which the propeller travels (*i. e.* the time-intervals from first hauling to opening, and from opening to shutting) varies so much with the rate of the steam-winch (an inconstant) and with the rolling of the ship. If there is any swell, the strain on the line as the ship rolls to leeward sends the propeller round at a greatly increased rate. While, however, venturing to criticize the method, I accept the positive results without any reserve, so far as they are published. They have been most recently summarized by Prof. Brandt [5], and show a mesoplanktonic fauna which rapidly diminishes in numbers below 100 fathoms, together with a large number of dead organisms which are slowly settling to the bottom. Prof. Hensen [6]

[1] Though theoretically perfect and simple, this method of investigating Mesoplankton appears to me to present two practical objections to its use: the one, that such an enormous amount of material must be collected as will take years for its proper identificaiton, before a comparison of surface and deep nets can be instituted; the other, that much of the deep material must inevitably be reduced to soup by pressure against the open tow-net in its long passage upwards; only forms with a strong skeleton (Radiolaria, Copepoda, &c.) can be expected to arrive fairly unbroken. In a closed net the resistance of the water does not appear to press the contents of the net against the meshes in the same way.

[2] C. Chun: Bibliotheca Zoologica, i.

[3] C. Chun: Bibliotheca Zoologica, vii., and SB. Akad. Belin, 1889, p. 519.

[4] V. Hensen, Ergebn. d. Plankton Expedition, Methodik der Untersuchungen, p. 106.

[5] K. Brandt: Verh. Gesellsch. deutschen Naturforscher und Aertze für 1895, Lübeck, p. 107.

[6] V. Hensen: Reisebeschreibung der Plankton Expedition, p. 28.

maintains the accurate locking of his net as against Prof. Agassiz's criticism, and makes a very pregnant remark on the point:—"Das Netz ist aber nur das Mittel um beweisende Fänge möglichst rein zu erhalten, der wirkliche Beweis ist die Beschaffenheit des Fanges."

The above summary represents briefly the results and conclusions of the chief writers who have studied the question experimentally: in the case of Prof. Agassiz, negative results have led to the assertion of an Azoic zone; in the case of the 'Challenger,' the 'National,' and Prof. Chun, positive observations have led to the conclusion of the existence of a Mesoplankton, but in these cases the mechanism of locking the net has not been sufficiently certain to escape the criticisms of the opponent school. With their results the less extensive experiments of the Prince of Monaco ('l'Hirondelle'), the 'Pola,' and the 'Gazelle' are in general accord.

Results of the Cruises of the 'Research,' 1896 *and* 1897.

In commencing to work at this question, I attempted to construct a locking-gear with which not even Prof. Agassiz could find fault; with the view, firstly, of finally settling the question of the existence of a Mesoplankton, secondly, of endeavouring to ascertain definitely, in a small area and on a small scale, what animals habitually lived in, and what animals descended to, the mid-water strata (matters of very great importance from the standpoint of oceanic distribution).

I venture to submit that, as long as the Law of Gravity holds good, the absolute closure of my net is indisputable, for it is effected by gravity. It is not only certain in the actions of opening and shutting (gravity being here also the motive power), but, when shut, the net-frame closes so tightly that nothing larger than the net-mesh (1 mm. or ·75 mm.) can get into it, either going down or coming up.

This being so, my observations agree on general lines with those of Chun and the 'National,' and directly contradict the purely negative observations of the 'Blake' and 'Albatross' on which Agassiz bases his theory of an Azoic zone. I encountered animals at every depth down to 500 fathoms, the deepest water available.

The Faeroe Channel was indicated as a suitable district by the thermal conditions; the depth is small when compared with the great oceans, but the extremely low temperatures met with in the district are those of the greatest depths in open oceans. As regards every thing but pressure, which appears to be an unimportant factor in determining distribution, the conditions of life at 500 fathoms in the "cold area" of the Faeroe Channel seem to be those of the greatest midwater depths known [1].

The Faeroe Channel is certainly a "closed sea" in the technical

[1] The Faeroe Channel was further indicated by the fact that H.M.S. 'Research' was surveying in the Orkney district. I cannot sufficiently express my obligations for the assistance rendered to me on so many sides—the recommendation of the Council of the Royal Society, the assent of the Lords Commissioners of the Admiralty, the suggestions of Admiral Sir William Wharton and Captain Tizard of the Hydrographic Office, and the uniformly patient help of Captain Moore and the other Officers of the 'Research' in both years.

sense of the word; but it is not a closed sea like the Mediterranean or Gulf of California, in which high temperatures are maintained to such a depth that there is practically no thermal limit to the descent of a surface organism. It is a closed sea on one side only, open to the Arctic Ocean on the North-east, with the isothermobath of 35° F. at about 250 fathoms, and in many places with a temperature of 30° F. at 500 fathoms. One is far from land nowhere in the Faeroe Channel; the single station of 1897 (Sta. 20) being only about a hundred miles from Cape Wrath, but far enough to be beyond the range of continental influence, in a case where the continental slope (100 to 500 fathoms) is steep, and no rivers discharge into the sea. The water at these depths is directly derived from the open Arctic ocean, and is practically unaffected by continental influence.

I would urge therefore, as against Prof. Agassiz, that planktonic animals can and do flourish at greater depths than 200 fathoms, even under oceanic and not neritic conditions: that they apparently flourish in utter darkness, at a temperature of 30° to 32° F., and at a depth of at least 500 to 400 fathoms.

The animals captured in the mid-water appear to fall into at least five categories:—(1) Organisms which range indifferently over all depths (eurybathic); of these, at any rate so far as the Faeroe Channel is concerned, *Calanus finmarchicus* may be taken as an example (p. 544 *ante*): (2) those which live habitually at great depths, and rarely or never appear at the surface, if at all, generally at night; of these characteristically mesoplanktonic animals, the Tuscarorida of the 'Challenger' Expedition, the deep-sea Schizopoda of Prof. Chun, *Sagitta whartoni* and *Conchœcia maxima* of the 'Research' collections[1] may be cited: (3) those which spend their earlier life at or near the surface, but of which adults are almost or quite confined to deep water, such as *Nyctiphanes norvegica*: (4) those which when adult inhabit the surface, but spend their larval life at considerable depths, such as Chun's Ctenophora: (5) the corpses of any of the foregoing classes, and of purely epiplanktonic animals, such as *Temora longicornis* (p. 546, table, *ante*).

With regard to this latter class, it will no doubt be urged by some naturalists that the capture of organisms in the Mesoplankton points, not necessarily to the fact of their living at great depths, but to their having been killed at the surface by unfavourable physical conditions and their subsequently sinking through the deeper strata towards the bottom. In many cases this is no doubt the true explanation of their presence in deep water; I have suggested this as the explanation of a particular haul of *Doliolum* (p. 583 *infra*), and of the presence of six species of Copepoda (pp. 548–9, *supra*) in the 'Research' collections from the Mesoplankton.

(1) In cases where *numerous* observations on *successive* days in the *same* district show numerous specimens of a species in the upper strata, but only a few specimens are rarely, not constantly, taken in the lower zones, this explanation probably holds good, especially in a Frontier district (p. 545) such as the Faeroe

[1] Proc. Zool. Soc. 1896, p. 992; 1897, p. 523.

Channel, where hotter and colder surface currents are constantly at war.

(2) This explanation may probably be further extended to cases such as those of the six Copepoda already mentioned (pp. 548–9); they appear to be southern (warm-water) forms, driven by the North Atlantic Drift into higher latitudes (colder temperatures) than they can bear. Although southern forms, none of them were taken at the surface in 17 hauls, five were captured once and one twice in 13 Mesoplankton hauls ; all six were few in numbers.

(3) A different explanation seems reasonable in the case of species which are taken in numbers and with regularity at considerable depths, but appear rarely or never at the surface (if at all, then generally at night). It is to me inconceivable that the destruction of such a small surface population should produce dead specimens in such abundance and with such regularity in the deeper strata. *Euchæta norvegica*, *Metridia longa*, and *Pleuromma abdominale* (pp. 543 and 547) are examples of this distribution ; they seem to be forms which, at any rate in these latitudes, exhibit a preference for a mesoplanktonic existence, but which can and do exist at the surface also under certain circumstances. Two of the species are Arctic type-forms, which in these latitudes seek deeper (colder) water, and may perhaps eventually be taken very much further south as Mesoplankton than they have as yet been recorded in surface collections.

(4) When a species is taken in equal abundance and with equal regularity both in Mesoplankton and Epiplankton, it seems fair to infer that it is eurythermal and eurybathic; it does not seem possible that all the deeper specimens are deep merely because they are dead and sinking. For example, the list of the captures of *Calanus finmarchicus* on the ‘ Research ’ (p. 542) seems to exclude such a possibility.

It seemed worth while to cite these instances of criteria, which may be applied in dealing with collections of Plankton from various zones, if the observations are numerous enough and sufficiently near together in time and place to permit of any general conclusions at all being drawn. Most mesoplanktonic specimens are dead when they arrive inboard ; the sudden alterations of pressure and temperature, and the damage by the net itself, are most fatal ; further, decay is so retarded at low temperatures in sea-water, that not even microscopical examination can be relied on as evidence of the life or death of the organism at the moment of capture. The criteria applied above may be expressed thus :—

Specimens at surface	Specimens below	Species belongs to
Numerous, constant.	None, or occasionally a few.	Epiplankton.
Numerous, constant.	Numerous, constant.	Epiplankton and Mesoplankton.
None, or occasionally a few.	Numerous, constant.	Mesoplankton.

The table on pp. 542–3 showing the vertical distribution of the 'Research' Copepoda in the Faeroe Channel, seems to me to offer convincing proof of the existence of a living Mesoplankton. If the forms which I caught at great depths were all dead, there would be more dead species in the district than live ones, which seems absurd; the average number of species per haul is ·88 in the Epiplankton and 1·38 in the Mesoplankton. Further, the deep water would contain an abundance of dead specimens of a species, such as *Euchæta norvegica*, of which there were practically no specimens at the surface to be killed; which also seems absurd. Again, if the destruction at the surface is so extensive as the death-hypothesis would imply, some specimens at least of *Temora longicornis*, and of all such forms as are abundant at the surface, ought to be captured in the lower strata; yet this species was not once taken in the Mesoplankton.

In concluding this discussion of the general question, I would strongly urge that any attempt, seriously to investigate the Mesoplankton in future, should be made, not at random stations all over the ocean, but in a limited area, one which presents as far as possible uniform conditions throughout, and may be presumed to contain a similar fauna throughout; for only by *numerous successive hauls at all depths* can that careful comparison be made, which will enable the observer to assign to each organism the proper significance of its occurrences.

DOLIOLUM (DOLIOLETTA Borgert[1]) TRITONIS, Herdm.
= *D. denticulatum* Herdman[2].

This species presented no new anatomical features for record. As Herdman points out[2], some specimens are cylindrical rather than of the characteristic barrel-shape; he assigns this to imperfect preservation. A comparison of my specimens from different stations with specimens of other animals from those stations, leads me to believe that the alteration in shape is due to damage in the tow-net by pressure. The smallest sexual specimens which still carried the stalk of attachment to the "Pflegethier" were about 5 mm.; it had been lost in one of 7 mm. length.

The horizontal distribution of this species was enormously extended by the 'National' (Plankton Expedition); till 1889 it had, I believe, only been taken in the Faeroe Channel, the North Sea, and off the Hebrides; the 'National' captured it in that year over nearly the whole of their course, from the Labrador Current right down to the South Equatorial Drift.

The appearance of huge swarms of sexual forms of *D. tritonis*

[1] A. Borgert: Thaliacea der Plankton Expedition.—C. Vertheilung der Doliolen. 1894.

[2] W. A. Herdman: Trans. Roy. Soc. Edinburgh, xxxii. p. 101.

in the Faeroe Channel is very perplexing. On the second and last days out of eight in 1896, they were at or near the surface in enormous quantities (96 to 140 specimens in a haul of 10 to 15 minutes); on the other six days, they were not only scarce or absent at the surface, but could not be found even by the deep-water net. Our position was altered several times between the two days of their swarming. This seems to imply that *D. tritonis* occurs in patches, with a few outliers in between the patches. Similar swarms of this species were observed in the Faeroe Channel by the 'Triton' in 1882 [1], by the 'Holsatia' in 1885, by the 'National' in 1889.

Brandt [2], in an interesting discussion of swarms such as these, seems to incline to the view that they are produced by wind and current action; but it is a little difficult to imagine how the effect of these agents would gather scattered organisms into a broad swarm in the open sea, except in an eddy or backwater; although they might make "wind-rows" in the open sea, or swarms in a closed area such as the Mediterranean. Further, if wind and current were the main direct agents in collecting swarms of *D. tritonis*, other organisms of the same powers of locomotion ought also to swarm at the same time; this is not my experience, nor, so far as I know, have other observers recorded this as a feature of the case.

I should prefer for the present to regard a swarm of *D. tritonis* mainly as the result of a period of great reproductive activity. In the case of an organism with a rapid power of multiplication and definite reproductive periods (whether due to food, temperature, or other causes), a very large number of individuals will soon be produced nearly simultaneously; if they have but little power of self-locomotion, *as long as they lie in the track of fairly uniform wind and current*, such as the North Atlantic Drift ("Gulf Stream"), *there seems to be no reason why they should be parted one from another.* In an eddy, such as the Sargasso Sea, where there are no constant winds or constant currents, the tendency will probably be for every little shift of wind to part them. The swarms of various organisms met by the 'National' were apparently all in the track of great ocean-currents, and were conspicuously absent from the Sargasso Sea.

If my suggestion is correct, then in still or steadily moving water a few *Doliolum* "Ammen," fairly close together, will produce a crop of "Pflegethiere" by asexual generation more numerous than themselves; and although we do not know the rate of reproduction of the "Amme" in throwing off "Pflegethiere," still that each "Pflegethier" may throw off an enormous number of sexual forms is obvious from the hundreds of buds on the stolon of each Pflegethier. The rate of reproduction is extremely *rapid*; and I see no reason to believe that in a constant current the family would not move forwards as a whole.

[1] "At times the Doliolum appeared to be in vast banks, where they were very numerous; between these banks there were always a few stragglers." (Murray in Herdman, *op. cit.* p. 112.)

[2] Brandt: in Reisebeschreibung der Plankton Expedition, p. 356 (1892).

It would appear also that the reproduction (throwing off) of sexual forms is *periodic*, from the following facts :—

The 'Research' specimens consisted of very numerous fully-grown sexual forms, a few much smaller sexual forms, and a few large 'Pflegethiere." Other observers[1] have recorded much the same for the same time of year (July, August).

Taking this in conjunction with the fact that, in my collections at any rate, sexual specimens of intermediate size, between the less than 5 mm. and the more than 9 mm. specimens, were very scarce, it would appear that the swarms were due to a period of simultaneous throwing off of numerous sexual forms: their existence and growth being, naturally, only possible when, as Borgert suggests, the conditions of food, temperature, &c. are favourable.

The above remarks apply to the 'Research' collections of 1896. In 1897 we were able to collect on one day only. On this occasion *Doliolum* was rare at the surface (like everything else), and the bulk of the catch was at a considerable depth. The small specimens were, proportionately to the large, very much more numerous at the surface than in the collections of 1896; the larger forms seemed to have sunk, like almost everything else, under the influence of very cold and somewhat boisterous weather. The following table gives the numbers taken :—

Sta.	Haul in fathoms.	Temperature.	Specimens.
20 *e.*	0		16 large[2], 4 small
20 *f.*	0		4 ,, 0 ,,
20 *g.*	40 to 0		1 ,, 25 ,,
20 *a.*	200 to 100		0 ,, 0 ,,
20 *b.*	300 to 200		11 ,, 0 ,,
20 *c.*	400 to 300		3 ,, 0 ,,
20 *d.*	500 to 400		130 ,, 9 ,,

As they were almost absent from the Mesoplankton during the 1896 cruise, I should not like to suggest, without more extended observations, that the deeper specimens were at so great a depth and so low a temperature, of their own free will. It seems to me probable, although there was nothing in their appearance either to suggest or to contradict it, that, in the haul 20 *d*, the net struck a swarm which had been killed by cold or other unfavourable circumstances, and was slowly settling to the bottom. The only differences between the specimens from 20 *c* and 20 *d*, and those surface-specimens which were living when brought on board, was that the digestive coil was blue in the deep-water specimens, brown or reddish in the surface specimens. Experiment would easily determine whether this was a post-mortem change or not.

[1] "Such vast numbers..... with a very few exceptions of much the same size" (no Pflegethiere noticed); Herdman, *op. cit.* p. 111.—"Erst bei genauerer Durchsicht fand ich unter ihnen, wenn gleich in weitaus geringerer Zahl, Pflegethiere und auch Ammen"; Borgert, *op. cit.* p. 61. "Ammen" were not observed among the 'Research' specimens.

[2] Three were "Pflegethiere."

On the Occurrence of *Doliolum nationalis* (Borgert) in British Waters.

By the courtesy of Mr. E. T. Browne and of Mr. E. J. Allen, the Director of the Plymouth Laboratory, I have been able to examine specimens of the alleged *Doliolum tritonis* from Valentia and Plymouth. These southern specimens prove to be *D. nationalis* Borgert[1]; they differ from *D. tritonis* not only in their much smaller size, but in the point of origin and attachment of the branchial lamella. A further difference between the species, not discussed by Borgert, is shown by the relations of the intestine: in *D. tritonis* (correctly figured by Herdman[2]) this is short, thick, and sharply curved on itself; in *D. nationalis* (correctly figured by Borgert, pl. v. fig. 4) it is long and slender, and, after a nearly straight course posteriorly, it is only slightly curved forwards, often not so much so as he has figured.

D. nationalis appears to be a southern and warm-water form. It has only been described hitherto from the collections of the 'National' (German Plankton Expedition) in 1889: it was absent until the 'National' struck the true Gulf Stream (37° N. 59° W., surface temperature 79° Fahr.); from there it occurred with greater or less regularity through the Sargasso Sea, North Equatorial, Counter Equatorial ("Guinea Current"), and South Equatorial Drifts, right up to the mouth of the English Channel (49° 7′ N., 5° 8′ W., surface temperature 52° Fahr.), where one specimen only was captured. It appears to be only an occasional visitor to our shores, probably under the influence of prevalent south-westerly winds and warm weather; it occurred at Plymouth and Valentia in 1893[3] and 1895[4].

Parathemisto abyssorum (Boeck).

This species according to Hansen[5] and Sars[6] is probably identical with *Hyperia oblivia* Kröyer; a view now accepted by Bovallius[7]. *H. oblivia* Spence Bate, appears to be not identical with either of the above.

Its distribution vertically and horizontally is a little perplexing, so far as our information goes at present.

i. It lives in cold water, apparently at the surface, in Greenland seas (Kröyer[8] and Hansen[5]), and in the Murmanske Hav, North of Russian Lapland (Hansen[9]).

ii. It lives in cold water at great depths—from 1710 to 160

[1] *Op. cit.* p. 581 *supra*.

[2] *Op. cit.* p. 581 *supra*, pl. xx. fig. 1.

[3] W. Garstang: Journ. Mar. Biol. Assoc. iii. p. 222. See also p. 210 for an account of the weather that year.

[4] E. T. Browne: Journ. Mar. Biol. Assoc. iv. p. 171.

[5] Hansen: Malacostraca marina Grœnlandiæ occidentalis.

[6] G. O. Sars: Crustacea of Norway, vol. i. p. 11.

[7] Bovallius: Kongl. Svenska Vetenskaps-Akad. Hdlg. xxi. p. 251.

[8] Kröyer: "Grönlands Amfipoder," Vidensk. Selsk., nat.-math. Afh. vii. p. 229.

[9] Hansen: Dijmphna Togtets zool.-bot. Udbytte, 1886, Krebsdyr, p. 28.

fathoms at 6 stations of the Norske Nordhavs Expedition [1]; all along the West Coast of Norway up to Finmark from 100 to 200 fathoms (Sars [2]); in the cold area of the Faeroe Channel (H.M.S. 'Research,' 1896, 530 to 220 fath.).

iii. It appears to come up to the surface from great depths at night, in the Faeroe Channel (H.M.S. 'Research,' 1896, Station 15 *d*); it has been taken off the Shetlands [3], and in the Faeroe Channel by the 'Triton' in 1882.

iv. It has been recorded from shallow waters round our coasts: from Banff (Edwards [4]): from the Forth [5]; once, a single specimen, from the Clyde (Robertson) [6]; off St. Andrews (McIntosh); from Valentia, where what appeared to be very young specimens of this species were taken in profusion by Messrs. A. O. Walker and E. T. Browne. Mr. Walker also informs me that he has received specimens 5 mm. in length from off Galley Head, co. Cork.

Now the curious fact about the specimens from Valentia, Galley Head, and the Firth of Forth is that they are all very small, ranging from 2 to 5 mm.; whereas in the Faeroe Channel they are mostly about 7–10 mm. in length, and specimens from the Norwegian North Atlantic Expedition reached the length of 17 mm. The length of the Banff specimens is not given. In all probability the small size of the British specimens of this sub-Arctic form indicates either (1) that the species attains a smaller size under increased temperature; or (2) that the larger adults are oceanic, and come inshore to breed, dying or retreating again to the open sea afterwards (this is Mr. Walker's suggestion); or (3) that the small and apparently young specimens of our coasts normally live in the open sea but nearer the surface than the adults, and are only driven on to our shores in heavy weather, or by a southerly current.

I have nothing to adduce either for or against the first suggestion. Against Mr. Walker's suggestion, it may be urged that the adult forms have not been recorded from inshore waters, and would surely have been noticed if they arrived in great numbers to breed. For, one feature of the appearance of this species on our coasts is that it generally arrives in enormous numbers (Firth of Forth, Banff, Valentia in 1896; they were less numerous, but plentiful at Valentia in 1897): this would imply the presence at some time of numerous parents, which have never been recorded.

The third suggestion appears to me to be likely to prove the correct solution; namely, that both young and adults normally inhabit open water, the young living nearer the surface and being brought to our shores as occasional visitors under special circumstances of weather and current. The clue is to be found in an

[1] G. O. Sars: Norske Nordhavs Expedition, Crustacea, vol. ii. p. 37.
[2] G. O. Sars: Crustacea of Norway, vol. i. p. 11.
[3] A. M. Norman: Rep. British Association for 1868, p. 287.
[4] Edwards: Journ. Linn. Soc. ix. p. 166.
[5] Sir John Murray kindly sent me a sample of these.
[6] Robertson: Trans. N. H. Soc. Glasgow, n. s. ii. p. 69 (1890).

observation of Sars[1]:—"A much smaller form, scarcely exceeding 5 mm. in length, but otherwise wholly agreeing with the typical species, I have met with in less depth [than 100 fathoms] and occasionally even near the surface of the sea." Edwards, in the paper already cited, speaks of their being "cast on shore during gales from the North in most enormous and incalculable numbers," and of "a ridge or wall of these animals extending more than a hundred feet in length, and varying from 1 to 2 inches in height and breadth, which had been washed up by the sea." He evidently considered them to live normally out at sea, and to come inshore occasionally "in search of food perhaps."

There are of course other forms, such as *Nyctiphanes norvegica*, which are known to inhabit the upper strata when young, and to descend normally to greater depths when adult. Other forms again are known to appear in the North Sea only at times when a strong set of southerly current brings down an Arctic or sub-Arctic Fauna[2].

I have discussed the distribution of this form at some length because it seems to me to illustrate our utter ignorance of the normal habitat and occasional appearance of some "British" species,—conditions which are fundamental factors in the distribution and bionomics of marine organisms, and which can only be elucidated by patient observation and *detailed records* all round the coast-line.

Parathemisto abyssorum may be fairly regarded as a member of the Mesoplankton in the Faeroe Channel: it occurred in seven out of thirteen deep-water hauls; and in one out of three hauls which began at or over 300 fathoms and finished at the surface; it occurred in only one out of twenty-five hauls between 100 and 0 fathoms, and then at midnight and very abundantly (15 *d*). It is also apparently a cold-water form by preference, as it did not occur in either of the deep hauls in the "warm area" (19 *a*, 480 to 350 fms.; 19 *b*, 480 to 0 fathoms).

[1] G. O. Sars: Crustacea of Norway, vol. i. p. 11.

[2] C. Chun: Beziehungen zwischen den arktischen und antarktischen Plankton. Stuttgart, 1897, 8vo.

CONTENTS (*continued*).

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